Consultation on a UK Low Carbon Hydrogen Standard
Zemo Partnership Response

Zemo Partnership, previously known as LowCVP and established in 2003, is a public-private partnership working to accelerate the transition to zero emission and sustainable transport in the UK. Around 200 organisations are engaged as members from diverse backgrounds including automotive and fuel supply chains, vehicle users, academics, environment groups and others. The Partnership became a not-for-profit company limited by guarantee in April 2009 and receives roughly half its funding as a direct grant from the DfT, together with funding directly from member companies.

This response is from Zemo Secretariat to specific questions in the Consultation on a UK Low Carbon Hydrogen Standard. Zemo Partnership has recently published two studies[1] related to low carbon hydrogen that will accompany this consultation response:

- Low carbon hydrogen well-to-wheel pathways study (July 2021)
- Hydrogen vehicle well-to-wheel GHG and energy study (October 2021)

Consultation Questions

Q1. Do you agree that the standard should focus on UK production pathways and end uses whilst supporting future export/imports opportunities? Please expand on your response.

Yes. A low carbon hydrogen standard has a key role to play in setting a benchmark for low carbon hydrogen production and supporting the commercialisation of various production technologies in the UK. GHG emissions associated with hydrogen production are heavily influenced by primary energy sources, subsequently a low carbon hydrogen standard should focus on UK production pathways and energy sources including UK electricity grid, natural gas supply chain and renewable energy. This will ensure representative GHG emissions are derived for different low carbon hydrogen pathways specific to the UK. Future export opportunities are unlikely to materialise until significant volumes of hydrogen are produced domestically, potentially from 2040. It is likely that the UK will import hydrogen from Europe and further afield from 2030 onwards, as such a low carbon hydrogen standard should extend to imported supply chains.

Q2. Would there be benefits in developing the standard into a certification scheme? Yes/no. Please provide detail.

Yes. Given the nascent low carbon hydrogen market in the UK, both in terms of supply and adoption, a low carbon hydrogen certification scheme would be a highly valuable market intervention for the UK, especially in the near term. This would be beneficial for establishing consumer/end user confidence in the GHG performance of different low carbon hydrogen production pathways, including the downstream supply chain. A second benefit could be to ensure that hydrogen imported into the UK is 'low carbon', thereby effectively contributing to UK decarbonisation goals.

[1] https://www.zemo.org.uk/work-with-us/fuels/projects/examining-hydrogen-production-pathways-and-use-in-vehicles.htm

Certification would serve to provide independent verification of a low carbon hydrogen producer's product(s) GHG and sustainability performance. Certificates would provide value as a 'guarantee of origin' when exporting low carbon hydrogen in the future, giving the UK a competitive advantage. It could also differentiate renewable hydrogen, if the primary energy source for producing green hydrogen is identified. Export of low carbon hydrogen internationally is unlikely to materialise for some time. As a result of this, it would seem appropriate to focus effort on developing a low carbon hydrogen certification scheme specifically for the UK's domestic low carbon hydrogen market.

Existing and evolving international hydrogen certification schemes (EU CertifyHy and Australian Guarantee of Origin scheme) are structured on a 'point to production' GHG emission boundary. Whilst this approach is useful for creating Guarantees of Origin for different low carbon hydrogen production pathways, and facilitating hydrogen to be tracked regionally and internationally, Zemo is of the opinion that a UK certification should encapsulate the entire hydrogen supply chain GHG boundary – 'to point of use'. This should cover hydrogen production including CCS, storage, distribution and dispensing. Three carbon intensity figures could be presented on a Low Carbon Hydrogen Certificate for approved production pathways: a 'Total' GHG emission intensity value, then split into 'Hydrogen Production' and 'Downstream Supply Chain' GHG emissions. Adopting this route could help provide data that would enable alignment with international schemes.

A hydrogen producer is likely to have multiple downstream supply chains (and purity requirements) for different for end users. For example, low carbon hydrogen produced from a renewably powered electrolyser will have a different downstream supply chain for road fuel customers, compared to an industrial feedstock customer, giving rise to nuances in GHG emission intensities. Zemo suggests that BEIS creates a scheme that certifies low hydrogen supply chains as 'industrial', 'transport', 'heat', 'power', 'export'. Adopting this approach could deliver an accurate, transparent, and representative framework for certifying hydrogen GHG emission performance for specific economic sectors. This could also bring about transparency in verifying hydrogen produced to different purity standards – ie 'low purity grade' hydrogen for use in internal combustion engines or as an industrial feedstock, and 'high purity grade' hydrogen for use in fuel cells. The purity grade of each hydrogen supply chain could be identified on a Low Carbon Hydrogen Certificate (a specification would need to be defined for different purity grades). This would give value to end users, especially in the transport sector, in terms of confidence in purchasing high purity hydrogen for HFC vehicles.

BEIS should be aware of existing renewable fuel/energy assurance and certification schemes in the UK. The REA Ltd manages the Green Gas Certification Scheme[2] which focuses on biomethane. This aims to 'track' biomethane from the point of production (AD plant) to an end user, via injection and distribution through the natural gas grid. The scheme is predominantly exploited by companies purchasing biomethane to decarbonise heat and power, providing them with Renewable Guarantees of Origin. The GHG emission threshold for biomethane aligns with the Renewable Heat Incentive and is based on a life cycle methodological boundary. It has been suggested that this scheme could be expanded to track 'green hydrogen' in the future.

Zemo manages a Renewable Fuels Assurance Scheme[3] that provides independent verification of liquid and gaseous renewable fuel supply chains in terms of GHG emission and feed stock sustainability performance. End users are HGV and NRMM operators. Zemo's scheme aligns with the life cycle GHG emission thresholds, and sustainability standards, set under the RTFO. We have additional traceability requirements to ensure that fleet operators are purchasing RTFO 'approved' renewable fuel, including blends of renewable fuel with fossil fuels. Zemo has created 'renewable fuel

[2] https://www.greengas.org.uk/
[3] https://www.zemo.org.uk/work-with-us/fuels/the-renewable-fuels-assurance-scheme.htm

declarations' which are issued to fleet operators every three months for batches of renewable fuel approved under the scheme. These identify the renewable fuel production process, feedstocks, GHG intensity and emission savings (see Appendix 1). Our scheme entails an annual compliance audit using a third-party auditor.

Zemo has undertaken significant work engaging with the HGV and bus sectors in relation to accelerating the take up of sustainable low carbon fuels. A re-occurring theme from fleet operators is having certainty, transparency, and traceability, regarding the GHG emission and sustainability performance of different low carbon fuel supply chains. This is the main reason Zemo established the RFAS. Learning from this, Zemo is of the opinion that a low carbon hydrogen certification scheme would be valuable for different end users to provide assurance that they are purchasing low carbon hydrogen, and have robust information pertaining to its GHG emission intensity. Whilst a certification scheme can verify a hydrogen production process as being 'low carbon' and qualify for Government funding, consumers need to be confident that their hydrogen supply is 'low carbon'. A certification scheme must have robust supply chain traceability. Zemo suggests this could be achieved by using third-party verification to mass balance volumes of low hydrogen sold to a customer against volumes of hydrogen certified as 'low carbon'. End users could be issued with a Low Carbon Hydrogen certificate for batches of low carbon hydrogen supplied, to demonstrate its provenance and GHG emission intensity. This will eliminate any risk of a hydrogen producer supplying a mix of 'fossil' and 'low carbon hydrogen' but labelling their product a low carbon hydrogen.

Consideration should be given to how blends of hydrogen could be certified. For example, an end user purchasing hydrogen supplied at a 20% blend (with 80% methane) for industrial or domestic heating should receive independently verified GHG emission data regarding their hydrogen supply chain. A 20% blend of hydrogen will achieve circa 7% GHG emissions savings compared to natural gas, whereas a 100% supply is likely to achieve >70% savings, depending on the low carbon hydrogen production pathways. It is imperative that there is transparency and traceability of low carbon hydrogen supply chain GHG emissions, and sustainability, for end users.

Q3. a. Is international consistency important, or should the UK seek to develop a low carbon hydrogen standard primarily based on the UK context and criteria set out above? Please provide detail.

Given the infancy of an international low carbon hydrogen market, and certification schemes, it is recommended the UK develop a standard initially based on the UK domestic market. A low carbon hydrogen standard can evolve over time. GHG emission threshold and sustainability criteria, for UK and international regulations related to sustainable low carbon fuels such as the RED and RTFO, have become more stringent over time.

Zemo recommends BEIS harmonises a UK Low Carbon Hydrogen Standard with existing regulations such as REDII, RTFO and EU Taxonomy Regulations[4] which encapsulate a GHG emission threshold for sustainable low carbon fuels that include hydrogen. This will avoid confusion in the marketplace and investor community.

- RTFO - RFNBOs: 65% GHG emission savings compared to fossil fuel comparator
- REDII - RFNBOs: 70% GHG emission savings compared to fossil fuel comparator
- EU Taxonomy – hydrogen: 70% GHG emission savings compared to fossil fuel comparator

[4] https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

All the above regulatory examples are based on a life cycle methodology and adopt a fossil fuel comparator of 94 gCO_2e/MJ (RTFO will be moving to this figure from 2022).

b. If elements of a UK standard differ to comparable international standards or definitions, would this impact the ability to facilitate investment in the UK or cause issues for business operations across borders? Yes/no/unclear at this stage. Please provide detail. Unclear

c. If answering yes to 3b, what elements of existing low carbon hydrogen standards or definitions are most important to ensure international consistency?

Q4. a. Should the standard specify a list of hydrogen production pathways, which would be updated periodically or on request? Yes/no.

This could be helpful in terms of understanding which production pathways would be eligible for funding, but not essential, as the purpose of a GHG emission threshold is to set a benchmark for any hydrogen production pathway. It is also worth noting that as the primary energy source has such a significant influence on hydrogen production GHG emissions, consideration should also be given to listing 'energy sources' suitable for each production pathway.

b. If yes, we would welcome respondents' views on what production methods could have significant potential in the UK in the near term.

c. If no, we would welcome respondents' views on alternative options.

Q5. a. Do you agree that the standard should adopt one label of 'low carbon' hydrogen, or would it be valuable to have multiple categories?

Yes

b. If multiple categories, what benefits would we get from adopting this approach in terms of emissions reduction and consumer confidence?

Zemo suggests multiple categories are defined through a low carbon hydrogen certification scheme to account for different hydrogen purity specifications and supply chains for end users. This is elaborated in Question 2.

Q6. a. Do you agree that a UK low carbon hydrogen standard should be set at the 'point of production'?

No

b. If no, what would the advantages be of the standard making assessments at 'point of use' or 'point of use + in use emissions'?

<u>Transparency and accuracy for end users</u>
End users need to be confident of the carbon intensity of the hydrogen product they are purchasing, as such they will require data related to the entire hydrogen supply chain ('point of use'). Providing only a 'production' value is misleading. This is demonstrated in Table 1 below.

Table 1: GHG emission values for hydrogen produced by renewable electrolysis

Point of production GHG emission boundary: UK	Point of use GHG emission boundary: UK	Point of use GHG emission boundary: Imported H_2
Renewable electrolysis	Renewable electrolysis, compressed H2 road delivery to refuelling station	Renewable electrolysis, liquified H2 (grid), ferry transport to UK from the Netherlands, liquified H2 road delivery to refuelling station
0 gCO_2e/MJ	23 gCO_2e/MJ	33 gCO_2e/MJ

Imported hydrogen is likely to transported by sea vessel to the UK, with onboard hydrogen stored cryogenically (liquified). Given the high energy intensity associated hydrogen liquification and long-distance transport, it is essential that a Low Carbon Hydrogen Standard GHG accounting boundary covers the entire hydrogen supply chain (point of use.) If not, then GHG emissions will be underestimated to end users, and this could be perceived as lacking transparency.

Transparency regarding low carbon fuel supply chains is escalating for all types of end users, in particular organisations required to measure and report GHG emissions. In order to achieve 'net zero' GHG emissions, companies will need to address Scope 3 emissions which cover their products 'upstream' supply chains. The requirement for low carbon hydrogen supply chain GHG emission performance will become increasingly material over time. This provides a further value of a Low Carbon Hydrogen Standard assessment boundary being at 'point of use'.

<u>Measurement and mitigating of fugitive H_2 emissions</u>
A GHG boundary at 'point of production' risks omitting fugitive hydrogen emissions, which arise across the hydrogen supply chain. The benefit of a 'point of use' assessment would be to encourage the monitoring and control of fugitive hydrogen emissions. Given the indirect global warming impacts of hydrogen, mitigating fugitive emissions avoids unintended consequences.

<u>Harmonisation with existing domestic and international regulations which relate to low carbon H2</u>
The RTFO and REDII have established GHG emission thresholds for renewable fuels, including hydrogen, based on a life cycle methodological boundary. This is equivalent to an 'at point of use' assessment. EU Taxonomy Regulations were created as part of the EU Green Deal, establishing environmental standards for investors to use in their assessment of finance allocation, ensuring money is direct to sustainable commercial ventures. The regulations have set a GHG emission threshold for hydrogen based on a life cycle methodology. The financial community will increasingly refer to the guidelines when making investment decisions. The GHG emission assessment boundary for UK Low Carbon Hydrogen Standard should avoid deviating from existing UK and European regulation, related to low carbon hydrogen. This could lead to confusion in the marketplace. Furthermore, if BEIS is aspiring for private investors to collaborate on hydrogen production projects that are supported by Government funding, having alignment with GHG emission thresholds and assessment boundaries set in the finance sector's ESG guidelines would be advantageous.

A UK Low Carbon Hydrogen Standard framed on a 'point of production' assessment boundary would result in a different GHG measurement boundary applied to other low carbon fuels supported by UK Government. For example, the UK's Sustainable Aviation Fuel policy sets a GHG emission threshold based on life cycle boundary. The same applies in the heating sector notably the Green Gas Scheme. This disjointed approach could be considered as inequitable. Care would also need to be given to how GHG emission performance data is reported to end users. A potential risk of confusing end users could arise if companies supplying hydrogen supported under BEIS Zero Hydrogen Fund report their GHG emissions based on 'production' only, are also supported under the RTFO and reporting hydrogen supply chain (life cycle) emissions. A harmonised approach to measuring and reporting low carbon hydrogen GHG emission performance across Government policies is essential.

Alternative proposal for a Low Carbon Hydrogen Standard

Zemo understands that a UK Low Carbon Hydrogen Standard is required in the first instance to qualify hydrogen production plants for BEIS funding streams. How this standard will be integrated into future fiscal incentives has yet to be identified by Government. One could envisage fiscal incentives for end users to encourage adoption of low carbon hydrogen. This will subsequently require a GHG threshold based on a 'to point of use' assessment, given the different hydrogen supply chains for various end users.

Zemo proposes an alternative approach to defining Low Carbon Hydrogen Standard. To qualify for BEIS funding an 'at point of use' (covering the entire hydrogen supply chain) could be defined, with a sub target for the 'production pathway'. The sub target will allow a more stringent requirement for the production pathways, which is the focus of Government funding.

Low Carbon Hydrogen Thresholds

- Hydrogen supply chain: <33gCO_2e/MJ
- Hydrogen production: <18gCO_2e/MJ

Carbon intensity values could be presented by hydrogen suppliers as a 'Total GHG emission intensity', then split into 'Hydrogen Production' and 'Downstream Supply Chain' emissions. This format could be replicated in a certification scheme and presented on a Low Carbon Hydrogen Certificate for different supply chains. We propose production emissions are derived as far as possible from 'actual' energy and GHG emissions data, with downstream pathways being a combination of actual and default values. A similar methodology approach could be taken to the RTFO GHG emission methodology, where a set of default values are provided for different elements of renewable fuel's life cycle.

Q7. Which chain of custody system would be most appropriate for a UK low carbon hydrogen standard: a mass balance or a book and claim system? Please explain the benefits of your chosen option.

Mass balance would provide a suitable level of traceability and ensure the carbon (and sustainability) credentials of low carbon hydrogen are not physically separated from the actual volume of fuel/feedstock supplied. The mass balance system has proved successful under the RTFO, therefore same approach could be adopted for a low carbon hydrogen certification scheme.

Q8. Should other CoC options be considered instead? Yes/no. If yes, please provide detail.

Q9. a. If the system boundary was set at the point of production, should there be defined reference purity and pressure levels for a UK low carbon hydrogen standard?

No. Zemo is of the opinion the GHG accounting boundary should be at 'point of use'. Given the multiple end users of low carbon hydrogen setting one purity and pressure level could be challenging. For example, hydrogen used in fuel cells would need to achieve a very high spec of 99.999% purity, whereas hydrogen used in certain types of industrial boilers fitted with a catalyst require a slightly lower purity level 99.5%. Hydrogen used as an industrial feedstock or used in HGV combustion engines would not need to achieve high purity grade. If a low carbon hydrogen certification scheme is created, there could be place for 'labelling' the purity of the hydrogen supply chain certified.

b. If yes, what should they be?

c. If no, what are the benefits to not defining reference purity and pressure levels?

Q10. a. Should there be minimum pressure and purity requirements for hydrogen to meet the standard?

No

b. What could the potential implications of setting minimum purity and pressure requirements be?

Q11. a. Do you agree that embodied emissions should be omitted from the calculation of GHG emissions under a low carbon hydrogen standard, to ensure comparability with global and UK schemes?

Yes

b. If no, what are the benefits to including embodied emissions in the calculation of GHG emissions, and what should be done to ensure that hydrogen is on a level playing field to other energy vectors?

Q12. a. Do you agree that a UK low carbon hydrogen standard should include the global warming potential of hydrogen? Yes/no.

Yes - a GWP should be included, accounting for fugitive hydrogen emissions is crucial as hydrogen is an indirect greenhouse gas. BEIS will need to ensure that sources of hydrogen leakages are integrated into a GHG emission methodology. Leakages of hydrogen will arise across the hydrogen supply chain, another reason for a low carbon hydrogen standard to cover at 'point of use' GHG accounting boundary. BEIS should provide a default GWP emission factor as part of their GHG measurement guidelines. This GWP should be updated in line with improvements in scientific understanding of the climatic impacts of hydrogen. If the IPCC propose a value in the future, this could be adopted.

b. If no, are there other options for accounting for the GWP of hydrogen outside of a UK low carbon hydrogen standard that could support compatibility with existing standards/schemes?

Q13. a. Should a materiality threshold for total emissions be included in the life cycle assessments of hydrogen pathways?

No

b. If yes, what would the most appropriate level be and why?

Q14. a. Should CCU with proven displacement or permanence be included as an allowable benefit in GHG calculations under a UK low carbon hydrogen standard?

Yes. This should align with existing regulations and GHG accounting methodologies. An 'allowable benefit' should only be allocated with evidence of 'proven displacement and permeance'. Clear rules should be defined as to what constitutes as 'proven displacement' and 'permeance' in addition, and how a CO_2 emission reduction is accounted for in the GHG emission calculation. For example, is CCU treated the same if the CO_2 is converted into an electro-fuel or stored geologically in redundant oil wells. Timelines for permanence need to be defined, with robust evidence of permanence.

b. If yes, what should a suitable minimum time be for proven permanence and which applications should be eligible?

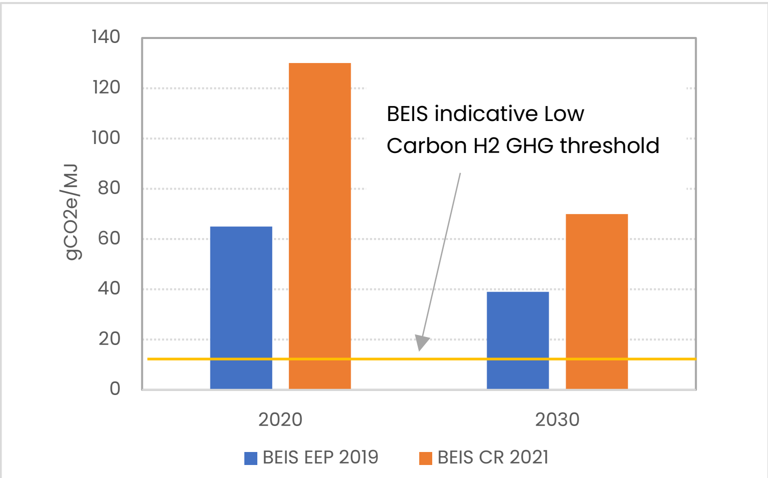
Q15. Should CCU credits only be allowed for biogenic carbon, and not allowed for fossil carbon sources?

Yes. This does however require clear guidelines with regards to how this is accounted in a GHG emission calculation and the source of carbon intensity values for different biomass feedstocks.

Q16. As the grid is decarbonising rapidly, so will grid connected hydrogen production pathways. How should government policy take into consideration hydrogen production pathways using grid electricity as primary input energy now? Please explain the benefits to the approach you have suggested.

Zemo has used data from their Low Carbon Hydrogen WTT Pathways Study to calculate GHG emissions for hydrogen produced by electrolysis in 2020 and 2030 using grid electricity, see Figure 1. The choice of electricity grid GHG emission factor has a significant influence on the resultant carbon intensity. Zemo's study adopted electricity grid GHG emission factors from the BEIS 2019 Emission and Energy Projections[5]. This has been presented in the chart below (blue), in conjunction with electricity GHG emissions calculated using the BEIS 2020 Company Greenhouse Gas Reporting (CR) conversion factors[6] (orange). The first point to highlight that irrespective of the GHG emission factors (annual average) adopted for grid electricity, the proposed Low Carbon Hydrogen threshold of 15-20 gCO_2e/MJ proposed in the consultation report, would not be achieved 'today' or in 2030. The second point to raise is that the BEIS EEP GHG emission factors result in the electrolysis pathway carbon intensity being 50% lower than the BEIS CR.

Figure 1: GHG emissions for H_2 produced by electrolysis in 2020 and 2030 using different BEIS GHG emission factors for UK grid electricity.



- Note: data is only for 'production' plant.

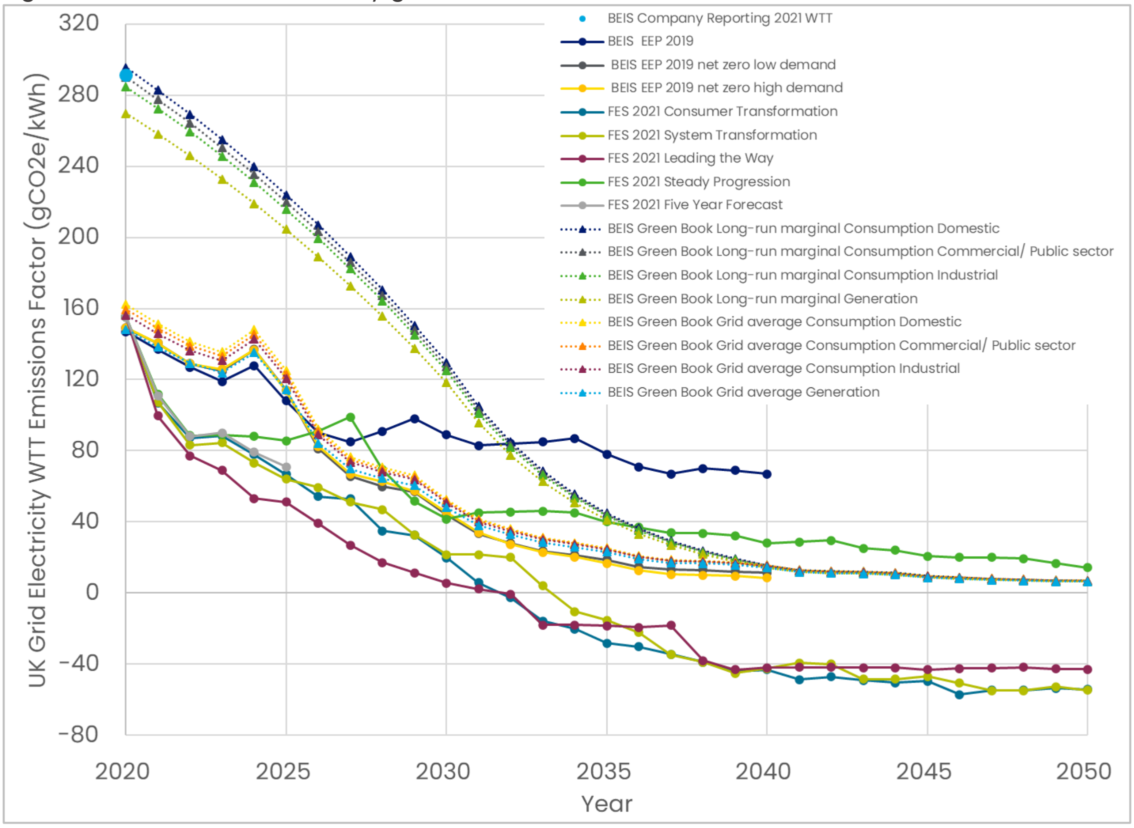
Zemo would like to highlight that a multitude of electricity grid GHG emission intensity values exist, including several produced by BEIS and National Grid – see Figure 2. BEIS should define which GHG emission factors should be adopted in a GHG emission calculation for determining low carbon

[5] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019
[6] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

hydrogen carbon intensity. A standard set of electricity grid GHG emission factors should be identified for electricity used for all hydrogen production process, and downstream pathways. The choice of electricity grid GHG emission factor is also relevant for electricity use for producing hydrogen from methane reformation and biomass gasification with CCS. The separation, compression, transport and injection of CO_2 will involve primary energy from grid electricity.

The RTFO team currently require UK grid electricity carbon intensity to be calculated using the 'current year' BEIS Company Greenhouse Gas Reporting values. A similar approach should be taken for the low carbon hydrogen standard GHG emission assessment methodology for consistency.

Figure 2: Published UK electricity grid GHG emission factors



Q17. a. What options should we consider for accounting for the use of electricity under a UK low carbon hydrogen standard? Do the options outlined seem appropriate? Are any of these particularly problematic? Please explain your reasoning.

BEIS are strongly recommended to consider the electricity requirement for ancillary equipment associated with CCS plant in particular CO_2 compressors for supercritical transportation and injection units for geological storage. Zemo suggests an analysis is undertaken by BEIS to determine the wider energy system implications of deploying CCS and the impact on the UK grid electricity. The high energy demand of CO_2 capture and storage, in conjunction with grid electricity demand for electrolysis, could result in unintended consequences by driving additional high carbon power generation.

If we assume 50% of Government's 5GW hydrogen production is from ATR+CCS, Zemo estimates that more than 5 million tonnes of CO_2 would need to be captured and stored in 2030. The estimated ancillary power (electricity) requirement is in excess of 600 GWh per annum from 2030. A ten-fold increase in blue hydrogen production to 50GW, and concurrent CO_2 transport and storage, raises the electricity demand to 6000 GWh/yr.

(Based on an electricity requirement of 425 MJe/tCO_2 for CO_2 compression, pipeline transportation and injection into on-shore geological storage, reference BEIS Low Carbon Hydrogen Options Report, and using a value of exported CO_2 per kg H2 from Zemo H2 pathways WTT model, with 95% capture rate for ATR with CCS.)

b. Of the options considered, should further conditions be included to mitigate any negative impacts or potential unintended consequences, such as driving additional high carbon power generation, and what could these conditions be?

Q18. What evidence should BEIS consider ahead of making decisions around the use of electricity as primary input energy for hydrogen production?

The existence of multiple GHG emission factors for UK grid electricity in the public domain, including several produced by BEIS. BEIS Company Greenhouse Reporting GHG emission factors are typically two years behind the date of publication. This could have implications to determine current year grid electricity GHG emission intensity. Future projections of UK electricity grid GHG emission intensity are highly varied as shown in Figure 2 above. It is also worth reiterating the wide divergence between '2020' electricity grid emission factors reported in BEIS Company Greenhouse Gas Reporting, compared to '2020' factors presented in BEIS Emission and Energy Projections – see Figure 1.

BEIS may wish to consider what constitutes 'low carbon electricity', defining a GHG emission threshold or specific generation methods e.g. wind power, nuclear.

Q19. How should low carbon electricity use in hydrogen production be accounted for in order to support the deployment of hydrogen production via electrolysis, whilst avoiding unintended consequences such as increased generation from high carbon power sources (impacting grid decarbonisation)?

The use of low carbon electricity should align with requirement sets under the RTFO, as these have involved detailed consultation with stakeholders and significant work to address unintended consequences.

Q20. Should a UK low carbon hydrogen standard include a requirement on additionality and why? Please explain the benefits to the approach you have suggested.

Yes. It is vital that the use of electricity for producing hydrogen avoids diverting renewable electricity from other uses or encouraging additional high carbon power generation for the UK electricity grid. This risk becomes more acute in the future as demand on the UK electricity grid increases as a result of electrification of the vehicle parc and heating. Requirement for additionality in terms of new renewable energy generation should mirror those set under the RTFO.

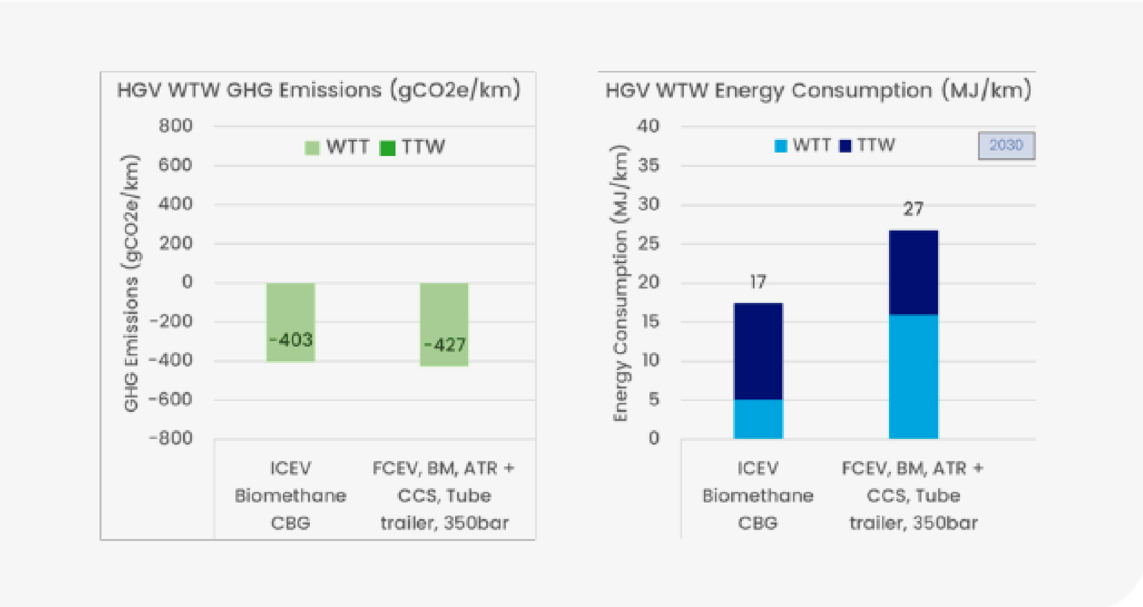
BEIS might wish to consider the requirement for additionality to also cover ancillary power for capture and storage CO_2 - e.g. energy for compression, transport and injection into on-shore or off-shore geological storage. As demonstrated in the example earlier, the electricity requirement could be very large.

Q21. Should additionality considerations also apply to renewable heat and other input energy vectors such as biomethane, in the same vein as for low carbon electricity and why? Yes/no. Please

explain the benefits to the approach you have suggested.

Producing green hydrogen using biomethane as a feedstock for the SMR or ATR processes could place pressure on domestic UK biomethane supply; this is a limited resource. An unintended consequence could materialise whereby biomethane is diverted from decarbonising other sectors such as heat and road transport. Zemo's hydrogen vehicle WTW study, demonstrates the higher energy consumption associated with producing green hydrogen using biomethane as feedstock compared to biomethane used as fuel in a gas truck, see Figure 3. The WTT (light blue) energy consumption is more than 50% higher for the ATR+CCS with biomethane feedstock.

Figure 3: WTW GHG emissions and energy consumption, biomethane truck versus hydrogen truck



- Biomethane (CBG) used in the gas HGV produced from biogenic waste with 40% manure, leading to GHG negative WTT GHG emission intensity, due to manure methane credit.
- WTT: Well-to-Tank GHG emissions fuel production TTW: Tank-to-Wheel vehicle tailpipe GHG emissions

Q22. a. Should waste fossil feedstocks be considered with counterfactuals under a UK low carbon hydrogen standard? Yes/no. Please explain the benefits to the approach you have suggested.

Yes, this should align with RTFO GHG emission methodology for 'recycled carbon fuels'.

b. What are the potential implications of supporting the use of any particular waste streams in hydrogen production?

Q23. What is the most appropriate way to account for hydrogen produced from a facility that has mixed inputs (high and low carbon)? Please explain the benefits to the approach you have suggested.

The option to have separate consignments or averaging, with the average meeting a benchmark has a balance between flexibility and avoiding risk, however, this should be reviewed in the light of decisions made in RED II and the RTFO.

Q24. What are the most appropriate units to calculate GHG emissions of low carbon hydrogen?

gCO_2e/MJ LHV.

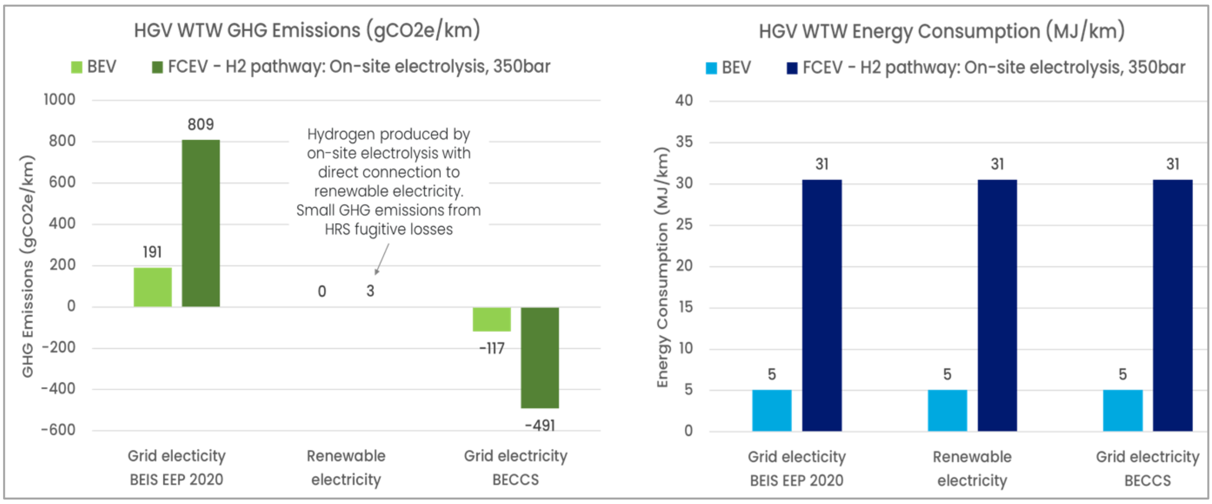
Q25. What allocation method should be adopted for by-product hydrogen and why?

Difficult to comment as there is not an agreed approach in standard LCA methodology.

Q26. Should the standard allow for negative emissions hydrogen to be reported?

Yes, but with care. Negative emissions could be reported separately as a credit; with low carbon hydrogen production pathways reported as zero GHG emission intensity. Caution should be exercised with negative emission hydrogen pathways, notably BECCS. The plots in Figure 4, from Zemo's Hydrogen Vehicle WTW study, illustrate that less energy efficient production pathways can result in larger negative GHG emissions: the fuel cell vehicle, powered by hydrogen produced from BECCS grid electricity appears to give the lowest GHG emissions but it requires more energy per km than the battery electric vehicle. Safeguards would be required to avoid promoting energy inefficient options and to make the best use of limited biomass resources.

Figure 4: WTW GHG emission and energy consumption for HFC and BEV truck, varying the source of electricity for electrolysis and battery charging.



Q27. a. Should non GHG impacts be taken into account? Yes/no.

Yes.

b. If yes, what criteria or factors should be taken into account and how?

The production of low carbon hydrogen is associated with a range of potential environmental and societal impacts, these are identified in Table 2 below. Zemo strongly recommends that a Low Carbon Hydrogen Standard GHG emission threshold is accompanied by sustainability criteria – we propose this covers three themes:

- protection of biodiversity
- energy and resource conservation
- pollution prevention and control.

It is imperative that the expansion of low carbon hydrogen supply chains does result in unintended environmental and societal impacts. Zemo recommends that BEIS publishes an environmental impact assessment to fully appreciate the nature and potential scale of environmental and societal risks associated with different low carbon hydrogen production pathways. Appropriate measures should be established as early as possible to mitigate unintended negative impacts. Consideration could be given to requesting that hydrogen producers monitor and report data on a variety of these parameters as part of information gathered from BEIS funded projects.

Table 2: Non-GHG impacts associated with low carbon hydrogen production and suggested requirements for mitigation.

Energy usage	Hydrogen production is energy intensive; this could place constraints on UK grid and renewable electricity supplies. Potential to increase natural gas demand. Zemo's WTT Low Carbon Hydrogen Pathways Study revealed 181-100 MJ of energy is required to produce 1kg of hydrogen. This is significantly higher than producing conventional fossil fuels and renewable fuels. Requirement for best practise in plant energy efficiency. 'Additionality' to be required to ensure new renewable electricity generation.
Water consumption	Electrolysis, methane reformation with CCS (water for cooling). Requirements for water conservation, especially if electrolysers source fresh water supplies from aquifers in water stressed regions.
Air quality	SMR and ATR fitted with CCS, depending on the type of catalyst used in the CCS plant exhaust emissions can include nitrosamines[7], this air pollutant has been identified as carcinogenic. Additional risk of NO_x emissions, problematic in urban areas which exceed NO_2 air quality standard. Hydrogen production plant should be regulated under UK Environmental Permitting Regulations, air pollution emission limits set and monitored.
Protection of biodiversity - direct and in-direct land use change	BECCS pathways, involving the use of biomass with CCS, the cultivation of biomass could give rise to negative impacts to biodiversity, as well indirect impacts. BEIS to introduce biomass sustainability criteria in line with RTFO and REDII.
Protection of marine biodiversity	Electrolysis – on/off shore: desalination of sea water generates saline waste which requires appropriate disposal. CCS plant – transportation of CO_2 by pipeline and geological storage could result in CO_2 leakage. This could result in a detrimental impact to marine ecosystems (and impact human health if a CO_2 cloud rises to shoreline). Requirements for monitoring CO_2 and leakage mitigation.

c. If no, please set out your rationale for your answer.

Q28. Given the many potential end uses of hydrogen, and the rapid expansion of low carbon supplies required, do you agree that an absolute emissions threshold be adopted, rather than a percentage saving based on a fossil comparator? Yes/no. Please provide detail.

7 https://ukair.defra.gov.uk/assets/documents/reports/cat09/2006240802_Impacts_of_Net_Zero_pathways_on_future_air_quality_in_the_UK.pdf

Yes. Zemo suggests BEIS consider other GHG emission thresholds that exist in regulations for low carbon hydrogen and potentially aligning with these e.g. RTFO, REDII, EU Taxonomy, even if converting percentage savings based to an absolute value. These are based on a life cycle accounting methodology. BEIS should look to regularly review a GHG emission threshold and tightened over time.

Q29. Should the standard adopt a single threshold or several, and why?

See question 6, Zemo propose two thresholds.

Q30. a. Should the GHG emissions threshold be set at a higher level in the early stages of hydrogen deployment, with a trajectory to decrease over time? Yes/no. Please explain the benefits to the approach you have suggested.

b. If yes, should this decreasing trajectory be announced from the offset? Yes/no. Please explain the benefits to the approach you have suggested.

Q31. What would be an appropriate level for a point of production emissions threshold under a UK low carbon hydrogen standard? Please set out your rationale for your answer.

BEIS suggested threshold for a 'point of production' GHG emission boundary, seems appropriate: 15-20 gCO_2e/MJ.

Zemo suggested threshold for a 'point of use' GHG emission boundary could be 27-33 gCO_2e/MJ.

(Zemo's WTW hydrogen vehicle study indicates: 27 gCO_2e/MJ would be expected to give ~70% GHG savings in 18t GVW HFC truck compared to diesel.)

Q32. a. Could some net zero compliant hydrogen production pathways be disadvantaged by the introduction of an emissions threshold set at 15-20gCO2e/MJLHV? Yes/no.

b. If yes, please explain which methods are likely to be disadvantaged and why.

Q33. a. How could we ensure that a low threshold does not negatively impact projects on a trajectory to net zero and learning by doing at the early stages of hydrogen market development?
b. What impact could this have on the UK achieving 5GW production capacity by 2030?

Q34. a. Should the UK low carbon hydrogen standard provide for some limited leeway on the threshold for existing hydrogen production facilities? Yes/no. Please explain the benefits to the approach you have suggested.

b. If yes, is a 10% leeway suitable? Yes/no.

Q35. What would be an appropriate level for a UK low carbon hydrogen standard if it were considering point of use emissions? Please set out your rationale for your answer.

Q36. Which type of organisation would be best placed to deliver and administer a Low Carbon Hydrogen standard? Please include examples where possible of effective delivery routes for comparable schemes.

Zemo interprets this question to mean 'the delivery and administration of a certification scheme' rather than a Low Carbon Hydrogen Standard. BEIS should have overarching responsibility of a low carbon hydrogen certification scheme (and the associated standard), with the administration lead by a company with expertise in auditing and renewable fuel/energy certification schemes.

Q37. Should default data, actual data or a hybrid approach be used to assess GHG emissions? Please explain the benefits to the approach you have suggested.

A hybrid approach is suggested. There is a risk that using default carbon intensity data for hydrogen production, storage and distribution relies on values not specific to the UK. Given most hydrogen production technologies are yet to be commercialised, robust default values are not available.

Q38. What should the options be for reporting and verification of low carbon hydrogen? Do any of the options outlined seem appropriate? Are any of these particularly problematic?

For hydrogen producers receiving Government fiscal support, there should be requirements for monitoring and reporting performance from funded projects for several years. This would assist in providing more real-world energy consumption and GHG emission data for calculating different low carbon hydrogen production pathways GHG emissions. E.g. hydrogen and CO_2 fugitive emissions, CCS plant exhaust stack CO_2 and CH_4 emissions, energy use for ATR/SMR + CCS and energy use of CO_2 separation, compression, transport and storage. For methane reformation, and gasification, with CCS pathways, hydrogen producers could be required to undertake exhaust stack emission monitoring once a year to demonstrate on-going CO_2 capture performance of the CCS plant.

Under a low carbon hydrogen certification scheme, hydrogen producers should undergo continued verification of compliance against the low carbon hydrogen standard, with annual reporting. Independent auditing of company data on an annual basis would seem appropriate.

Q39. Are any other options not listed here that are better suited for low carbon hydrogen reporting? Any thoughts on how possible trade-offs between accessibility and robustness or between accuracy and simplicity could be addressed?

Q40. What would be an appropriate frequency for verification or audit?

Q41. Over what period of time should the standard be introduced?

Recommend a certification scheme is piloted first, delivered in collaboration with a selection of low carbon hydrogen producers, recognised auditors, a technical advisory team and Government. This could be delivered over a twelve month period, then final scheme launched. Zemo took this approach when designing the RFAS: this proved highly beneficial and resulted in a successful scheme being rolled out.

Q42. Do you have any other comments relating to the carbon standard proposals set out in this document?

Zemo recommends BEIS develops a GHG accounting methodology for determining hydrogen supply chain (to point to use) carbon intensity. This should define a GHG emission threshold boundary and guidelines for GHG emission calculation. The following items are proposed for inclusion -

- Define key data inputs for different hydrogen production processes, identify GHG emission factors for primary energy specific to the UK (electricity, natural gas, biomass), GWP values for methane, nitrous oxide and hydrogen

- Electrolysis (on/off-shore) GHG emission calculation to include energy required for sea water desalination and deionised water as well electrolyser
- Account for upstream natural gas, biomass and electricity grid GHG emissions (Scope 3) as well as transmission and distribution losses for electricity and natural gas (Scope 2)
- Assumptions for fugitive methane losses in UK natural gas supply chain
- How to account for iLUC factors for biomass feedstocks
- How to account for biomass feedstock which receive a methane credit under REDII, e.g. manure used for biomethane production
- Identify what year electricity grid carbon intensity should be adopted, for example will this be today's value or when the plant is commissioned
- Provide guidance on how default and actual values are applied
- Recommend actual energy consumption values are used to determine GHG emissions for hydrogen production plant and CCS pathway including CO_2 compression, pipeline transport plus injection at on-shore or off-shore geological storage
- Fugitive emissions sources to cover - hydrogen production, storage, distribution, dispensing
- Combustion (Scope 1) GHG emissions (CO_2, CH_4, N_2O) for SMR, ATR, gasification with CCS pathways
- Fugitive CO_2 emission with CCS including CO_2 pipeline transport and at permanent storage location.

Zemo's Low Carbon Hydrogen WTT Pathways Study highlighted where robust data is lacking with regards to calculating hydrogen production emissions. These are: fugitive hydrogen emissions, CO_2 losses and energy required for CO_2 transport and storage, H2 gas grid transportation, liquification of hydrogen, ATR+GHR+CCS performance. BEIS could request real world data is obtained from funded hydrogen production plants to improve data fidelity. Zemo suggests BEIS require the following as a funding requirement: energy monitoring, CO_2 and H_2 fugitive monitoring.

BEIS should require evidence that SMR and ATR fitted with CCS can achieve >95% capture rate. This could include exhaust stack emission CO_2 and methane testing. The on-going performance of CCS equipment must be monitored to ensure continued abatement performance. Suggest plants are fitted with continuous emission monitoring equipment, with annual data submitted to BEIS for three years after grant funding. Zemo anticipates large hydrogen plants will be covered under Environmental Permitting Regulations – this could be a requirement from BEIS as part of funding qualification. This could be considered under wider sustainability criteria.

Appendix 1 – Zemo Renewable Fuel Declaration for Renewable Hydrogen.

Renewable Fuels Assurance Scheme

Zemo Partnership

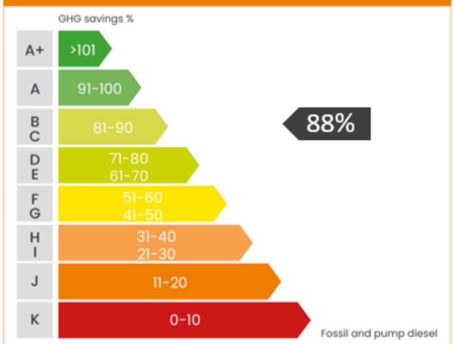
Renewable Fuel Declaration

Fleet Operator & Supplier Information			
Customer name	GE logistics	Customer address	Enfield Lock
Renewable Fuel Supplier	Green H2	Renewable fuel supplier identifier	GH/14/21
Category of renewable fuel supplier	Supplier	Declaration period	Jan – Mar 2021
Declaration number	G/01/21	Date declaration issued	April 2021

Renewable Fuel Description	
Renewable Fuel	Renewable hydrogen
Renewable fuel blend supplied	100%
Volume of renewable fuel sold	100,000 kg
Production process	Electrolysis
Depot based or centralised production	Centralised
Country of production	UK
Distribution to refuelling station	Compressed hydrogen by road tanker

Greenhouse Gas Emission Performance	
GHG emission intensity of renewable fuel supply chain	9 gCO2e/MJ
GHG emissions savings	88%

GHG Emission Savings Compared to Fossil Fuel



Feedstock Sustainability	
Renewable fuel feedstocks	Electricity
Method of renewable electricity generation	Wind Power
Country(s) of origin	UK

Further information

GHG emissions relate to Scope 3 emissions in corporate GHG emission reporting (Greenhouse Gas Protocol)
GHG emission savings of more than 100% means that the renewable fuel is carbon negative.

Insert copy

Zemo renewable supplier approval date:	Insert copy	**RFAS website:** www.zemo.org.uk